High Pressure Sensor Based on Fusion Bonding.
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Silicon pressure sensors are widely used in a large number of applications due to the attractive performance characteristics such as sensitivity, long term stability, and last but not least, cost effective manufacturing of pressure sensor dies.

It is, however, well known [1] that the encapsulation of conventional pressure sensor dies is delicate and expensive for many industrial and other demanding applications due to the inherent topology of conventional silicon chips. Stress de-coupling [2], media compatibility [3] and long term temperature stability are often issues, which must be dealt with either through unconventional chip-design or advanced packaging schemes.

The pressure sensor presented in this paper is an absolute pressure sensor with piezoresistiv read out. It is based on fusion bonding and designed to operate in refrigeration- and fluid power systems. The basic idea has been to design a sensor chip that is optimized for simple and low-cost packaging, where the induced stress caused by the packaging is reduced, with the sensing area directly exposed to the medium and with a high burst pressure. To achieve these objectives the sensor is realized in a needle shape with a hexagonal cross section. This particular shape allows for a compact and cheap packaging solution. Because of the special needle shape the sensing region is separated from the package materials implying that the stress caused by these materials is minimized. The electrical parts such as piezo-resistors and interconnections are encapsulated in a sealed reference cavity by fusion bonding and thereby shielded from the media. The pressure sensor has a high burst pressure because of a small pressure exposed area. The sensor operates in the pressure range from 0 to 200 bar at temperature ranging from 0 °C to 120 °C and it has a burst pressure of about 3000 bar.

Fabrication of the pressure sensor involves fusion bonding of two preprocessed wafers where surface roughness, cleanliness, pattern formation on the bonding surface and wafer-bow are issues to be dealt with. After the fusion bonding the needle shape and membrane are realized in a KOH-etch. On fig. 1 a completed sensor is shown before encapsulation. Fig.2 shows the step response of a defect sensor with a leaking reference cavity. By the use of special test devices with a high pressure sensitivity and smallest possible reference cavity volume, one can obtain a limit of detection of leak-rates for a fusion bonded sealed cavity down to 10^{-16} Pa m^3/s.

Sensor design, fabrication and performance will be presented as well as recent results on the bonding quality, reliability and their dependence on the process parameters.

References

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[2] V.L.Spiering et. al., “On Chip decoupling zone for package-stress reduction”, *Sensors and Actuators* **A39**, (1993), 149-156.
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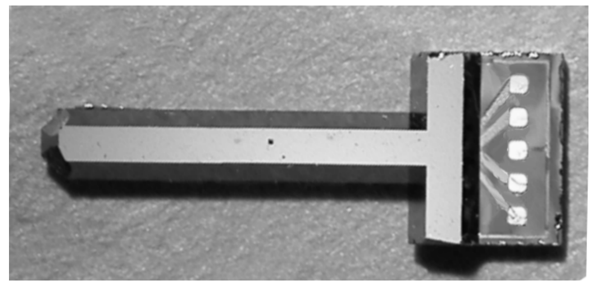
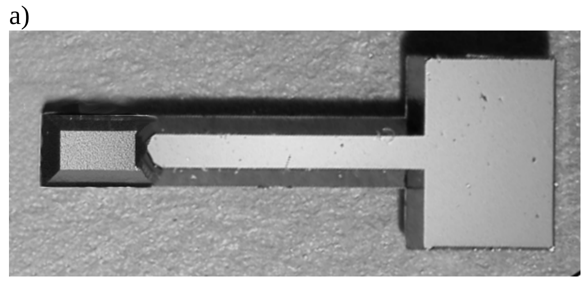


a)



b)

c)

Fig. 1 Photos of the needle shaped pressure sensor.
a) Shows the contact area with the bond pads. b) Shows the other side of the sensor with the membrane area to the left at the needle tip. The whole length of the sensor is 7 mm. c) Shows the layout of the electrical parts. The resistors and interconnections are buried in oxide in between the two wafers.

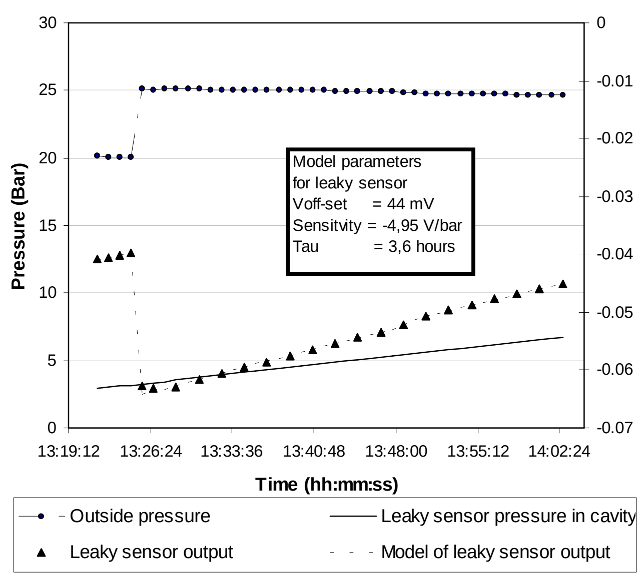


Fig. 2. Measured step-response data for a 30 bar absolute pressure sensors including estimates of characteristic time constant for the step-response decay (which imply a leak to the 800 pl reference cavity). Estimate of leak is based on a best fit to output voltage step response at an excitation voltage of 5V at 22°C. The actual leak-rate is $6{\cdot}10^{-12}$ Pa m^3/s and the limit of detection is about $2{\cdot}10^{-14}$ Pa m^3/s.